CLAIMS

What is claimed is:

1. A fluid processor comprising:

a pump for drawing a fluid from a fluid source through a fluid inlet and pressurizing the fluid;

a processor assembly for processing the fluid from the pump;

a process control system comprising: a flow splitter disposed between the pump and the processor assembly for diverting a portion of the fluid from the pump, a first flow restrictor for receiving the diverted fluid and directing the diverted fluid to the fluid inlet, a pressure relief valve disposed between the first flow restrictor and the flow splitter, and a second flow restrictor disposed downstream of the processor assembly,

wherein the flow splitter, first flow restrictor, second flow restrictor and pressure control valve are constructed and arranged to coact with each other to control the pressure and flow rate of the fluid in the fluid processor.

2. The fluid processor of claim 1, wherein the process control system maintains the pressure of the fluid in the processor assembly at least about the saturation point of the fluid at a predetermined temperature.

3. The fluid processor of claim 1, wherein the flow splitter is a filtration device.

4. The fluid processor of claim 1, wherein the flow splitter is a reverse osmosis device.

5. The fluid processor of claim 1, wherein at least one flow restrictor is a fixed setting flow restrictor.

6. The fluid processor of claim 5, wherein the fixed setting flow restrictor is a fixed length capillary tube.

7. The fluid processor of claim 1, wherein at least one flow restrictor is an adjustable setting flow restrictor.

8. The fluid processor of claim 7, wherein the adjustable setting flow restrictor is a metering valve.

9. The fluid processor of claim 1, wherein the pressure relief valve is a spring-loaded adjustable pressure relief valve.

10. The fluid processor of claim 1, wherein the fluid processor further comprises a check valve disposed upstream of the processor assembly.

11. The fluid processor of claim 1, further comprising a treatment assembly comprising a prefilter disposed upstream of the processor assembly

12. The fluid processor of claim 11, wherein the treatment assembly further comprises a reverse osmosis device disposed downstream of the prefilter.

13. The fluid processor of claim 11, wherein the treatment assembly further comprises a RODI apparatus disposed between the prefilter and the processor assembly, the RODI apparatus comprising a reverse osmosis device and an ion exchange device.

14. The fluid processor of claim 11, wherein the treatment assembly further comprises a RODI apparatus disposed downstream of the processor assembly, the RODI apparatus comprising a reverse osmosis device and an ion exchange device.

15. The fluid processor of claim 11, wherein the treatment assembly further comprises a RODI apparatus comprising: an ion exchange device disposed between the prefilter and processor assembly; and a reverse osmosis device disposed downstream of the processor assembly.

16. The fluid processor of claim 1, wherein fluid processor processes feed water to produce sterile water for injection.

17. The fluid processor of claim 1, further comprising:

a temperature sensor for measuring the temperature of the fluid in the processor assembly; and

a temperature controller for controlling the temperature of the fluid in the processor assembly.

18. The fluid processor of claim 1, further comprising an electronic control system for controlling the fluid processor, the electronic control system comprising:

a touch screen interface for providing readouts and operator input; and

a programmable logic controller for managing the electronic control system, the programmable logic controller comprising a main control circuit and a central processing unit and further, wherein the programmable logic controller is interfaced with a temperature sensor, a pressure transducer, a temperature controller, and a pump controller.

19. The fluid processor of claim 18, wherein the programmable logic controller is further interfaced with an endotoxin sensor having a signal conditioner, a flow rate meter having a flow sensor, and a conductivity meter having a conductivity cell.

20. The fluid processor of claim 19, wherein the endotoxin sensor, flow sensor and conductivity cell are disposed downstream of the processor assembly along a product line.

21. The fluid processor of claim 19, wherein the endotoxin sensor and conductivity cell are disposed downstream of the processor assembly along a discharge line.

22. The fluid processor of claim 19, wherein the endotoxin sensor, flow sensor and conductivity cell are disposed along a divert line.

23. The fluid processor of claim 1, wherein the processor assembly comprises:

a heat exchanger for recovering thermal energy;

a reactor for processing a fluid by heating; and

a heater for heating the reactor.

24. The fluid processor of claim 23, wherein the fluid processor further comprises a sanitization assembly comprising:

an isolation valve disposed immediately downstream of the fluid inlet;

a drain valve disposed at the lowest point of the fluid processor and between the pump and the processor assembly; and

a startup loop assembly comprising:

a startup flow restrictor disposed immediately downstream of the isolation valve and positioned along a first fluid path running from the isolation valve, the first fluid path running parallel to a second fluid path running from the isolation valve to the pump; and

a four-way valve disposed downstream of the startup flow restrictor and the pump, wherein the four-way valve has a startup position for directing the fluid from the startup flow restrictor to the reactor and a normal position for directing the fluid from the pump to the heat exchanger.

25. The fluid processor of claim 24, wherein startup flow restrictor is a fixed setting flow restrictor.

26. The fluid processor of claim 24, wherein the startup flow restrictor is an adjustable setting flow restrictor.

27. A method for sanitizing the fluid processor of claim 24 during startup, the method comprising:

connecting the fluid inlet to the fluid source wherein the fluid source has a line pressure of not less than about 10 psia and not greater than about 800 psia;

switching the four-way valve to the start-up position;

opening the isolation valve;

introducing fluid into the fluid processor at line pressure;

switching on the heater;

allowing steam generated by the heater to flow downstream of the reactor and exit at a fluid outlet; and

switching the four-way valve to the normal operation.

28. A method for sanitizing the fluid processor of claim 24 during shutdown and storage, the method comprising:

turning off the pump and heater;

closing the isolation valve;

allowing residual heat of the reactor to produce steam from the fluid in the processor assembly;

allowing the steam to generate a pressure in the processor assembly;

allowing the pressure to expel the fluid that is downstream of the processor assembly out through a fluid outlet;

opening the drain valve to discharge the fluid that is upstream of the processor assembly;

attaching a closure means to the fluid outlet when fluid ceases to flow from the fluid outlet; and

closing the drain valve when the fluid ceases to flow from the drain valve.

29. The method of claim 28, wherein the closure means is a container holding a sterile solution.

30. The method of claim 28, wherein the closure means is a filter

31. The fluid processor of claim 23, wherein the heat exchanger is a shell-and-tube heat exchanger and further, wherein a process fluid flows through a shell side of the heat exchanger and a product fluid flows through a tube side of the heat exchanger.

32. The fluid processor of claim 23, wherein the heat exchanger is a tube-in-tube heat exchanger and further, wherein a process fluid flows through an annular side of the heat exchanger and a product fluid flows through a tube side of the heat exchanger.

33. The fluid processor of claim 32, wherein the heat exchanger is a helical coil tube-in-tube heat exchanger.

34. The fluid processor of claim 33, wherein the reactor and the heater are nested within the heat exchanger.

35. The fluid processor of claim 34, wherein the reactor and the heater are disposed within a temperature homogenizer.

36. The fluid processor of claim 35, wherein the temperature homogenizer comprises a multiplicity of blocks, the blocks being joined together by fasteners.

37. The fluid processor of claim 35, wherein the temperature homogenizer is a unitary structure produced by casting and further, wherein the reactor is formed as an integral part of the temperature homogenizer.

38. The fluid processor of claim 35, wherein the temperature homogenizer is enclosed by an insulation jacket.

39. The fluid processor of claim 1, wherein the processor assembly further comprises:

a heat exchanger for recovering thermal energy;

a reactor for processing a fluid by cooling; and

a cooler for cooling the reactor.

40. The fluid processor of claim 39, wherein the heat exchanger is a helical coil tube-in-tube heat exchanger and further, wherein the reactor and the cooler are nested within the heat exchanger.

41. The fluid processor of claim 40, wherein the reactor and the cooler are disposed within a temperature homogenizer.

42. The fluid processor of claim 41, wherein the temperature homogenizer comprises a multiplicity of blocks, the blocks being joined together by fasteners.

43. The fluid processor of claim 41, wherein the temperature homogenizer is a unitary structure produced by casting and further, wherein the reactor is formed as an integral part of the temperature homogenizer.

44. The fluid processor of claim 41, wherein the temperature homogenizer is enclosed by an insulation jacket.

45. The fluid processor of claim 1, wherein the processor assembly comprises:

a helical coil tube-in-tube heat exchanger for exchanging heat between a process fluid and a product fluid;

a helical coil-shaped reactor nested within the heat exchanger for processing the process fluid to the product fluid by heating; and

a hot gas heater for heating the reactor.

46. The fluid processor of claim 45, wherein the processor assembly further comprises an insulated duct having a hot gas inlet at one end and a vent at the other end and further, wherein the heat exchanger is disposed within the insulated duct.

47. The fluid processor of claim 45, wherein the processor assembly further comprises a hot gas tube and an insulated enclosure having an opening at the top and further, wherein the heat exchanger is disposed within the enclosure and the reactor is disposed within the hot gas tube and further, wherein the hot gas tube is nested within the heat exchanger.

48. The fluid processor of claim 1, wherein the processor assembly comprises a multiplicity of heat exchangers for exchanging heat between a process fluid and a product fluid.

49. The fluid processor of claim 48, wherein at least two heat exchangers are connected together in parallel.

50. The fluid processor of claim 48, wherein at least two heat exchangers are connected together in series.

51. The fluid processor of claim 48, wherein at least one heat exchanger is a tube-in-tube type heat exchanger.

52. The fluid processor of claim 48, wherein at least one heat exchanger is a helical coil tube-in-tube type heat exchanger.

53. The fluid processor of claim 48, wherein at least one heat exchanger is a rope rug coil tube-in-tube heat exchanger.

54. A method for processing a fluid in a fluid processor, the method comprising:

drawing a fluid from a fluid source through a fluid inlet;

pressurizing the fluid from the fluid source;

diverting a portion of pressurized fluid to the fluid inlet with a flow splitter to form a recirculating loop;

controlling the flow rate and pressure of the fluid in the recirculating loop using a first flow restrictor and a pressure relief valve;

processing the fluid in a processor assembly

applying a backpressure to the fluid in the fluid processor using a second flow restrictor.

55. The method of claim 54, wherein the processor assembly comprises a tube-in-tube heat exchanger and a reactor and further, wherein processing the fluid further comprises:

directing the fluid through an annular side of the heat exchanger and into the reactor; and

directing the fluid from the reactor to a tube side of the heat exchanger.

56. The method of claim 54, wherein the processor assembly comprises a shell-in-tube heat exchanger and a reactor and further, wherein processing the fluid further comprises:

directing the fluid through an annular side of the heat exchanger and into the reactor; and

directing fluid from the reactor to a tube side of the heat exchanger.

57. The method of claim 54, wherein processing the fluid comprises heating the fluid.

58. The method of claim, 54 wherein processing the fluid comprises cooling the fluid.

59. The method of claim 54, further comprising removing particulates from the fluid.

60. The method of claim 54, further comprising removing oxidizable substances from the fluid

61. The method of claim 54, further comprising removing dissolved gases and electrolytes from the fluid.

62. The method of claim 54, wherein the fluid is feed water and processing the fluid produces sterile water for injection.

63. The method of claim 54, further comprising:

sensing the temperature of the processor assembly; and

controlling the temperature of the processor assembly

64. The method of claim 54, further comprising:

controlling the processor assembly through an electronic control interface, the electronic control interface comprising:

an touch screen interface for providing readouts and operator input; and

a programmable logic controller for managing the electronic control system, the programmable logic controller comprising a main control circuit and a central processing unit and further, wherein the programmable logic controller is interfaced with a temperature sensor, a pressure transducer, a temperature controller, and a pump controller.

65. A compact processor assembly suitable for use in a fluid processor, the processor assembly comprising:

at least one helical coil tube-in-tube heat exchanger for counter-currently exchanging heat between a process fluid and a product fluid, wherein the process fluid flows through an annular side of the heat exchanger and the product fluid flows through a tube side of the heat exchanger;

a reactor nested within the heat exchanger for converting the process fluid into a product fluid by heating;

a heater nested within the heat exchanger for heating the reactor; and

66. The compact processor assembly of claim 65, further comprising

means for maximizing the heat transfer from the heater to the reactor; and

means for minimizing heat loss to ambient.

67. The compact processor assembly of claim 66, wherein the means for maximizing heat transfer heat includes means for maximizing the stability of the temperature of the fluid in the reactor.

68. The compact processor assembly of claim 66, wherein the maximizing means is a temperature homogenizer enclosing the heater and the reactor and the minimizing means is an insulating jacket enclosing the temperature homogenizer.

69. A compact processor assembly suitable for use in a fluid processor, the processor assembly comprising:

at least one helical coil tube-in-tube heat exchanger for counter-currently exchanging heat between a process fluid and a product fluid, wherein the process fluid flows through an annular side of the heat exchanger and the product fluid flows through a tube side of the heat exchanger;

a reactor nested within the heat exchanger for converting the process fluid into a product fluid by cooling;

a cooler nested within the heat exchanger for cooling the reactor; and

70. The compact processor assembly of claim 68, further comprising

means for maximizing the heat transfer from the reactor to the cooler; and

means for minimizing the heat gain from ambient.

71. The compact processor assembly according to claim 70, wherein the means for maximizing heat transfer includes means for maximizing the stability of the temperature of the fluid in the reactor.

72. The compact processor assembly of claim 70, wherein the maximizing means is a temperature homogenizer enclosing the cooler and the reactor and the minimizing means is an insulating jacket enclosing the temperature homogenizer.